

The University of Chicago

STATISTICAL ANALYSIS OF FACTORS
WHICH MAKE FOR SUCCESS IN
INITIAL ENCOUNTERS
BETWEEN HENS

A PART OF A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF ZOÖLOGY

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STATISTICAL ANALYSIS OF FACTORS WHICH MAKE FOR SUCCESS IN INITIAL ENCOUNTERS BETWEEN HENS¹

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THE basic importance of initial encounters, among certain animals at least, in many different major groups of phenomena (Collias, 1943) makes it seem important to analyze the factors deciding the outcome of such encounters. To make such an analysis I have taken advantage of the remarkable fact that the first thing two strange hens will do upon meeting is to settle their future dominance relations either by fighting or by passive submission of one bird. Once established the social order is very stable and is easily ascertained at any time by noting which hens peck which without being pecked in return. The social order has been observed to persist a year or more with no change in the pecking order.

METHODS AND RESULTS OF ANALYSIS

Two hundred pair contacts were staged in a neutral pen using normal moderately inbred white leghorn hens from different flocks. These contests were conducted over a period of three years, and their original purpose was merely to serve as controls in experiments designed to test the influence of various injected hormones on the out-

¹ This article represents part of a thesis submitted to the faculty of the University of Chicago in partial fulfilment of the requirements for the degree of doctor of philosophy. I am indebted to my special advisor, Professor W. C. Allee, for suggesting that I work on this problem for a thesis, for facilities needed and valuable comments on the work. No claim is made by me to professional qualification as a statistician, and without the aid generously furnished by Professor Sewall Wright, who suggested and supervised the statistical procedure, this study would not have been possible. I wish also to knowledge assistance by Miss Catharine Z. Lutherman in gathering some of the data, and to express my appreciation to Dr. A. M. Guhl for permission to cite from his unpublished work.

come of initial pair contacts. The care and housing of the birds and the method of conducting the encounters have been described in a previous publication (Allee, Collias and Lutherman, 1939). Briefly, two hens from different flocks were caught, weighed, state of moult was noted, position in the social order in the home flock was recorded, and standard comb measurements (length plus height) were taken. The birds were then placed simultaneously in a strange pen purposely reduced to half size to insure closer association. The time of the latent period before contact and the length of the fight, if any, were recorded along with notes on general behavior of the birds toward each other. The statistical methods used in analyzing the results are described below.

By artificially increasing certain variables, it is often possible to discover which are real factors in deciding the outcome of initial encounters. This makes it possible to control those factors which can be readily controlled, and by the application of statistical analysis to evaluate the others and so to reach some idea of the relative importance of the different factors in a fairly normal situation. It is the extent to which prediction can be attained that is important, and the finer the discrimination possible, the more nearly will rules apply to the vast majority of individuals which cluster about the modes of species variability rather than merely applying to the less numerous variants at the extremes. The present report describes the progress attained toward this objective as related to success in initial encounters.

A. Nature of the Encounters

In a typical fight the birds first become oriented with respect to one another; as they examine each other the face becomes red and flushed, the neck hackles rise, the tail becomes more erect and the wings droop. The birds may then jockey for a favorable position or at once leap up and at each other and slash towards the head with the beak in an attempt to seize and bite their opponent's comb

or wattles. During the heat of battle the birds pay absolutely no attention to a human observer. The fight often lasts but a few seconds. The loser retreats and seeks to escape, its face pales, its feathers are depressed, it appears to be confused and panic stricken and looks for a place to hide, especially if closely and viciously pursued. The winner maintains much the same attitude as during the fight and only gradually does its excitement subside. Inhibition of the attack is based on experience, as well as subordination, since aggressive cocks or hens as a rule attack any strange individual, whereas attacks on flock mates are generally confined to relatively mild pecks. Fighting among hens, while often very strenuous, is much less severe than among cocks, and in the present series of encounters dominance relations were more often decided by passive submission of one bird than by an active battle.

B. Controlled Factors

1. *Sex.* As a rule cocks dominate hens when full grown (Schjelderup-Ebbe, 1935). Only hens were used in these experiments.

2. *Territorial defense.* Of 1,428 first meetings of domestic fowl observed over a period of 10 years Schjelderup-Ebbe (1922) noted that the home bird "wished" to fight in 93 per cent. while the strange bird "wished" to fight in only 32 per cent., and the home birds won 62 per cent. of the 476 battles observed. The courage of the new birds seemed lessened by their surroundings and they fought with less vigor. All the encounters reported in the present study were conducted in a neutral pen which was quite similar to a part of the home pens of the birds concerned.

3. *Social facilitation.* There is evidence that the presence of a powerful familiar despot betters the chances of its subordinates in contacts with strange individuals (Dr. A. M. Guhl, personal communication). Since in the present experiment never more than two birds were intro-

duced into the fighting pen at the same time, this factor does not complicate the results.

C. Statistical Analysis of Uncontrolled Factors

These factors included the following readily measured features: (1) size of comb as an indicator of male hormone output; (2) weight as a partial indicator of strength, relative size, including "impressiveness" and general physiological state; (3) social rank in the home flock as a presumed indicator of the "psychology of success"; and (4) state of moult.

Previous experience had demonstrated that very unaggressive hens could readily be caused to win all their encounters with normal hens and to rise in the social order by injecting them with testosterone propionate (Allee, Collias and Lutherman, 1939). Possibly size of comb has some "impressive" or bluff value (*ibid.*). However, Dr. A. M. Guhl (unpubl.) in this laboratory recently found that treatment of dubbed hens with testosterone caused such hens to rise in the social hierarchy; local application of this androgen induced considerable increase in comb size of normal hens, but had no influence on social rank. It had also been found that doses of thyroxin large enough to cause moulting and a marked reduction in body weight as well as to inhibit the gonads would considerably reduce the chances of a hen of winning its initial encounters (Allee, Collias and Beeman, 1940).

Size of comb was recorded in millimeters, weight in ounces, moult by arbitrary grades and social rank in terms of numbers of subordinates. For purposes of statistical analysis moult of the winner was simply treated as greater or less than the moult of the loser, while rank was adjusted for difference in size of flock by a transformed scale making use of inverse probability functions. For the latter purpose use was made of the following formula given me by Professor Wright.²

² $\text{Prf } \frac{x}{\sigma}$ is the area of the unit ($\sigma=1$) normal curve between the mean (0) and x/σ and prf^{-1} is the symbol for the inverse function and gives the devia-

$$\text{Adjusted rank} = \text{prf}^{-1} \left(\frac{\text{Number pecked} + \frac{1}{2}}{N} - \frac{1}{2} \right)$$

We are assuming that the bird is located at a point which dichotomizes a normal distribution in such a way that the subordinates are on one side and the dominants are on the other. The bird itself is assumed to contribute equally to both sides. The proportion of subordinates is thus taken as $\frac{\text{number pecked} + .50}{\text{size of flock}}$. The proportion of subordinates between the mean of the hypothetical scale and the rank of the given bird is then $\frac{\text{number pecked} + .50}{\text{size of flock}} - \frac{1}{2} = \text{prf } R$. The inverse function ($\text{prf}^{-1} R$) gives us the value of the adjusted rank on the hypothetical scale. The following diagrams may help to make this clear.

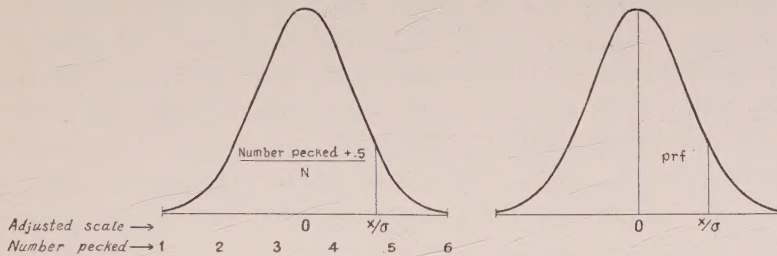


FIG. 1. Diagrams to illustrate statistical adjustment of rank in peck order to size of the home flock.

In a flock of 7 birds (maximum of 6 subordinates for highest bird) the adjusted rank for a bird which pecked 5 subordinates would be $\text{prf}^{-1} \left(\frac{5 + .50}{7} - .50 \right) = .79$. This formula tends to bunch together the birds near the center of the social scale on the assumption that the underlying factors which make for success would exhibit a normal distribution if a large enough population were considered. All the statistical methods used in this report were based on the same assumption. All modifications of the usual

tion (in terms of σ) that underlies the designated area. Tables of these functions are provided by Davenport and Ekas (1936).

statistical methods which are used were kindly provided to me by Professor Wright.

The first step was to correlate each factor with success. The two hundred fights, rather than the individual birds, have been taken as the units throughout in obtaining correlation coefficients. A preliminary tabulation indicated that even in contests conducted between the same pair of individuals at different times the results were frequently reversed. It must be remembered that these hens came from different flocks and did not associate with each other between these staged fights. If successive pair contacts are well spaced in time, each becomes essentially an initial contact. Hence such variability is not incompatible with the relative permanence of social order in stable flocks of hens. None of the data were grouped.

The variables that have been considered are the differences between the birds involved in the fight, not the absolute measurements. Each fight may be considered from the view-point of either bird as the one whose victory or defeat is to be used in describing the results and from whose grades in the various characters, those of the other bird are to be subtracted to obtain the differences. Thus a fight in which bird A, weighing 3 lbs. 8 oz., defeated bird B, weighing 3 lbs., may be entered in the correlation table relating success and difference in weight either as a "victory" associated with a difference of +8 oz. or a "defeat" associated with a difference of -8 oz. As this is an arbitrary matter, it is legitimate to make entries from both viewpoints, thereby making the marginal frequencies of the correlation table symmetrical (as in the case of a fraternal correlation table). In the correlations involving success, the complete table would have 200 entries in the category "victory" and 200 entries in the category "defeat." The total distributions of the differences in weight, comb size, rank and state of moult are necessarily symmetrical about zero.

In determining the signs of the entries, it is assumed that the winner of a fight stood higher than the loser on a

hypothetical scale describing the array of factors making for success. Thus "victory" is treated as positive, "defeat" as negative. A difference in rank is treated as positive if the first bird (*i.e.*, the one whose grade is to be treated as minuend) stood higher in the peck order of its flock than the second, according to the scale discussed above. With regard to the state of the plumage, it has seemed best to treat freedom from moult as highest in the scale and extreme moult as lowest. In this way, the differences which one might expect to find associated with success (*viz.*, those that go with greater weight, greater comb size, higher rank and relative freedom from moult) should exhibit positive correlations with success if, as turns out to be the case, this expectation is realized.

The correlations between success and the differences in the graded characters, weight, comb size and rank, were obtained by Pearson's coefficient of biserial correlation (in the form given by Kelley, 1923).

Let S be the difference between a first and a second bird on a hypothetical scale based on the factors making for success in fighting. A positive value implies that the first bird won, a negative value that it lost. It is assumed in the theory that the differences are distributed normally on this scale.

Let W be the weight of the first bird minus that of the second.

Let W_1 be a value of W in a case in which the first bird won.

Let W_2 be a value of W in a case in which the first bird lost.

$\bar{W}_1 = \Sigma W_1/200$, $\bar{W}_2 = \Sigma W_2/200$ are the means.

If each fight is entered in both ways $\bar{W}_1 = -\bar{W}_2$, $\bar{W} = 0$.

Thus $\sigma_w = \sqrt{\Sigma W^2/400} = \sqrt{(\Sigma W_1^2 + \Sigma W_2^2)/400} = \sqrt{\Sigma W_1^2/200}$ is the standard deviation of all differences in weight about zero.

The formula for biserial correlation is as follows:

$$r_{sw} = \left(\frac{\bar{W}_1 - \bar{W}_2}{\sigma_w} \right) \left(\frac{pq}{z} \right)$$

where p and q are the proportions in the two categories with respect to success and z is the ordinate of the unit normal curve at the point of dichotomy. In the present case $p = q = 1/2$, $z = 1/\sqrt{2\pi} = .399$. $r_{sw} = 1.253 \bar{W}_1/\sigma_w$.

Differences in comb size (C) and rank (R) were treated similarly.

The standard errors of these correlations were obtained from Soper's approximate formula as given by Kelley (1923).

$$SE_r = \frac{1}{\sqrt{N}} \left(\frac{\sqrt{pq}}{z} - r^2 \right) = (1.253 - r^2) / \sqrt{200}.$$

The case of moult (differences represented by M) requires further consideration. Three categories were recognized: more, equal and less moult. It is assumed that these represent a trichotomy of a normal distribution of a scale of graded differences. Let a, b and c be the proportions with more, equal and less moult respectively in any distribution. Assume that the threshold between more and equal moult is at $-.50$ on this scale and that that between equal and less moult is at $+.50$. The difference between these thresholds can be expressed as follows in terms of the standard deviation (*cf.* Wright, 1934a).

$$[\text{prf}^{-1}(a + b - .50) - \text{prf}^{-1}(a - .50)] \sigma = 1$$

If a frequency between mean and threshold comes out negative as calculated from $(a + b - .50)$ or $(a - .50)$ the sign of the inverse probability function is to be taken as negative.

Among the winners there were 16% with more moult than the loser, 32% with equal moult and 52% with less moult. This yields for the standard deviation of this category (σ_{M_1}).

$$\sigma_{M_1} = 1 / [-\text{prf}^{-1}(.02) + \text{prf}^{-1}(.34)] = 1.059$$

The location of the mean of the winners on our hypothetical scale can now be obtained.

$$\bar{M}_1 = .50 - \sigma_{M_1} \text{prf}^{-1}[a + b - .50] = .50 + 1.059 \text{prf}^{-1}(.02) = .553$$

Because of symmetry, the mean of the losers ($\bar{M}_2$) is $-.553$ on this scale.

The variance of the total (σ_M^2) is compounded of the average within the rows (both $1.059^2 = 1.122$) and that between them (which is $.553^2 = .306$). Thus $\sigma_M^2 = 1.122 + .306 = 1.428$, $\sigma_M = 1.195$.

The standard deviation of the total could also be calculated directly from the symmetrical trichotomy of the total ($a = .34$, $b = .32$, $c = .34$).

$$\sigma_M = 1 / [\text{prf}^{-1} .16 + \text{prf}^{-1} .16] = 1.212$$

The discrepancy between these estimates is due to the fact that if the distributions of the separate rows are normal (as assumed in calculating their means) the distribution of the total is more or less platykurtic, instead of normal (as assumed in the second estimate of σ_M). Properly it is this total (based on birds taken in both orders with respect to success and therefore equivalent to ones taken in random order) that should be considered as normal, but for consistency with the calculation of the row means, the estimate $\sigma_M = 1.195$ is used here. The error in assuming normality of the distributions within the separate rows does not appear to be important as indicated in some measure by the comparison of the two estimates of the total standard deviation.

The biserial correlation may now be estimated.

$$r_{SM} = 1.253 M_1 / \sigma_M = .580 \pm .065$$

This has been assigned a standard error by the same formula as in the preceding cases, although this is undoubtedly somewhat of an underestimate because of the nature of the scale. There is, however, no doubt of the significance of this correlation.³

In order to estimate the relative importance of the different factors it was necessary to take into account their correlations with each other. These correlations were obtained by use of the ordinary product moment formula in the case of differences in weight, comb, and social rank.

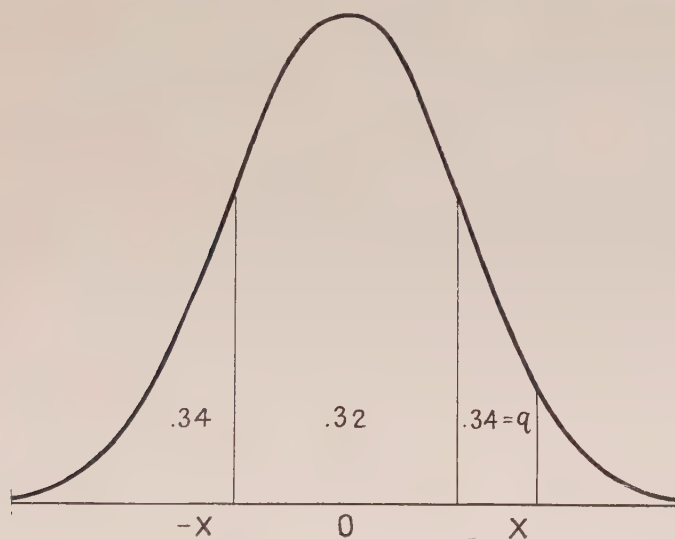


FIG. 2. Transformation of values for moult to a numerical scale on the normal probability curve.

Pearson's broad category method was used in the cases in which moult is involved. The marginal frequencies (34% more, 32% equal and 34% less moult) are here assumed to trichotomize a normal probability curve with unit standard deviation, a different scale from that used above. The mean of the middle category is obviously zero. The mean deviation (*d*) for the category "less moult" is given by the following formula in which *q* is

³ Professor Wright, personal communication.

the tail frequency (.34) and z is the ordinate at the threshold.

$$d = z/q = .3664/.34 = 1.078$$

The deviation of the category "more moult" is obviously -1.078 .

$$\sigma_d^2 = (.34d^2 + 0 + .34d^2) = .790$$

is the variance as estimated from the mean deviations. The true variance is 1.

According to Pearson's formula,

$$r_{MW} = \frac{\sum dW}{N\sigma_W \sigma_d^2}$$

The formulae for r_{MC} and r_{MR} are similar.

All these correlations between factors have been assigned standard errors by the usual formula, $\sigma_r = (1 - r^2)/\sqrt{N}$ although this is undoubtedly slightly too low in the cases involving moult, because of the coarseness of the scale.

We assume that the array of factors upon which the result of a fight depends includes cases in which differences in weight, comb size, state of moult and social rank are close indicators. In Figure 3 the correlations are known and are indicated by curved lines. The object is to find the value of coefficients measuring the influence along the paths indicated by arrows. An estimate can be obtained by the method of path coefficients (Wright, 1921, 1934a, 1934b) which in a symmetrical system such as used here is essentially the same as that of multiple regression, except for qualifications from the hypothetical character of the scale in the case of the differences in state of moult, social rank and success. The correlation between success and one of the factors such as weight may be analyzed into a direct contribution measured by the coefficient for the path from weight to success and three indirect contributions measured by the products of the coefficients along the paths from W through C , M , and R respectively to S . The correlations between success and the four factors provide four simultaneous equations which are identical with the normal equations of multiple regression.

$$r_{SW} = p_{SW} + p_{SC}r_{WC} + p_{SM}r_{WM} + p_{SR}r_{WR}$$

$$r_{SC} = p_{SW}r_{WC} + p_{SC} + p_{SM}r_{CM} + p_{SR}r_{CR}$$

$$r_{SM} = p_{SW}r_{WM} + p_{SC}r_{CM} + p_{SM} + p_{SR}r_{MR}$$

$$r_{SR} = p_{SW}r_{WR} + p_{SC}r_{CR} + p_{SM}r_{MR} + p_{SR}$$

Table 1 summarizes the correlation coefficients and the path coefficients resulting from solutions of the normal equations..

TABLE 1

CORRELATIONS AND PATH COEFFICIENTS RELATING DIFFERENCES IN CHARACTERS TO SUCCESS IN FIGHTS FOLLOWING INITIAL ENCOUNTERS

Difference	Correlation with success	Path coefficient relating to success
slightness of moult	.580 ± .065	.417
comb size	.593 ± .064	.354
weight	.474 ± .073	.111
rank in own flock	.262 ± .084	.209
Multiple correlation = $\sqrt{\sum r_p^2} = .748$		

TABLE 2

CROSS CORRELATIONS AMONG THE CHARACTER DIFFERENCES

Character differences		
Slightness of moult and comb		.379 ± .061
Slightness of moult and weight		.387 ± .060
Slightness of moult and rank		-.064 ± .070
Comb and weight		.440 ± .057
Comb and rank		.156 ± .069
Weight and rank		.220 ± .067

TABLE 3

DEGREE OF DETERMINATION OF SUCCESS BY INDICATED FACTORS

Moult	.174
Comb	.125
Weight	.012
Social rank	.044
Moult and comb, joint residual	.112
Moult and weight, joint residual	.036
Moult and rank, joint residual	-.011
Comb and weight, joint residual	.035
Comb and rank, joint residual	.023
Weight and rank, joint residual	.010
Total determination (= .748 ²) =	.560
Residual determination =	.440
	1.000

These results need some interpretation. The correlation coefficients measure the total influence direct and indirect, of the various factors. The multiple correlation coefficient (.748) indicates the correlation between the best linear function of all of the factors and success.

Because of inter-correlations, the correlation coefficients do not however give a reliable evaluation of direct effects of the factors. The relatively high correlations between moult, weight, and comb size may be an expres-

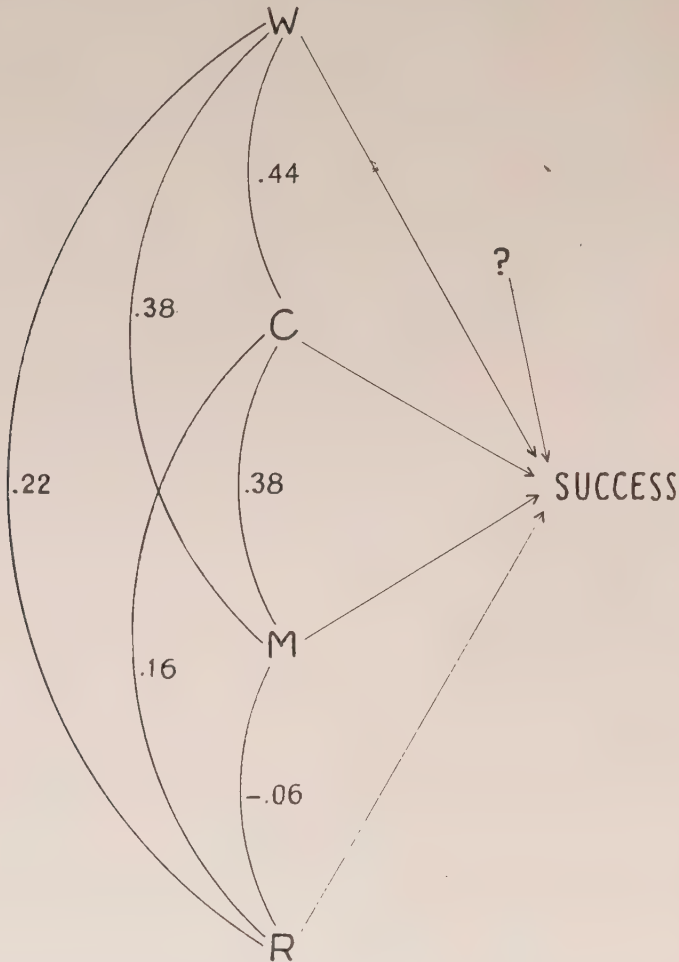


FIG. 3. Interrelations of factors influencing result of initial encounters.

sion of pituitary action but they can be more directly explained as being due in large part to a common factor which is presumably the amount of thyroxin which is present since this hormone in fairly large doses will in-

duce moulting, reduce weight and suppress the gonads, all of which are more or less associated with loss of combat. The correlation between social rank and weight (.220) between social rank and comb size (.156) are low. The correlation that does exist may be a result of the fact that differences in weight and androgen which helped decide the original rank have persisted in part. Social rank once decided is much less variable than is weight, size of comb, or state of moult, hence the correlation is low. Then, too, birds high in the peck order have precedence to food and probably thrive better. The very low correlation between moult and social rank ($-.064$) is probably of no significance.

Inspection of the tables indicate that according to the path coefficients, moult (absence) was the most important factor deciding success, followed by male hormone indicated by comb, social rank and weight in that order. The small influence of weight is noteworthy. Moult exerts the greatest relative influence, but exactly how it does this is not known since it has been statistically freed from its actions through weight or the gonads. Perhaps it tends to make the bird more retiring since moult is really a kind of physiological illness, perhaps it makes the bird more sensitive to blows received, and perhaps the loss of feathers renders a bird less able to maintain equilibrium and to fight effectively. Size of comb is one of the best convenient indicators of male hormone output which we know at present. Hens secrete male as well as female hormone and injection of androgen has been shown to have a very marked and stimulating effect on the outcome of initial encounters unlike injection of estrogen (Allee, Collias and Lutherman, 1939; Allee and Collias, 1940). Social rank is perhaps a somewhat objectionable criterion since it may conceal factors of the very nature we are trying to uncover. However, it was the most convenient indicator of the "psychology of success" available, and furthermore this objection is obviated to a substantial degree by the low correlations of moult, comb and weight

with social rank as compared to their relatively high correlations with success in initial encounters. The rather small importance of social rank as an independent factor as indicated by its path coefficient is also noteworthy in this respect.

The degrees of determination of the variance by the various factors reduce the results to a percentage basis and give a good idea of how the different factors influence variability in degree of success, acting singly and in combination. Acting singly, they necessarily exhibit the same order as their path coefficients since they are merely the squares of the former. Joint determination represents the contribution to variability (plus or minus) due to correlated occurrence of the two factors under consideration. The order of joint determinations obviously may differ from the order of the intercorrelations since the latter do not measure degree of influence on success. For example, moult and weight are more closely correlated than moult and comb, yet the joint determination by the latter pair is almost four times as great as that by the former pair which involves weight, a relatively ineffectual factor. One of the important properties of the degree of determination is that the sum of the components must be equal to 1. The general equation is $\Sigma d_{x.A} + d_{x.AB} = 1$, which is read, the sum of the determination of x due to A and the sum of the determination of x due to the correlation between A and B must be equal to 1 (Wright, 1921). This gives a means of estimating the percentages of unknown factors (residual) by subtraction. In the present case 56.0 per cent. of the factors are accounted for by the single or correlated action of moult, comb size, weight and social rank, and presumably the underlying factors of which they serve as more or less imperfect indicators are responsible for a somewhat similar percentage. It follows that 44 per cent. of the factors were not measured in this analysis or were not known.

D. Unmeasured and Unknown Factors

One possible way to account for the unknown factors lies in the probability that more accurate indicators of the underlying factors would have given higher values for the paths, cutting down the amount assigned to residual factors. This is not to assume that still other factors do not exist which are unrelated to these indicators.

There are certain known but unmeasured factors which influence success and may have complicated the results to an unknown extent in the present case. Among these are age, the behavior of the other bird, and previous fighting experience.

Young pullets up to at least 9 months of age are somewhat refractory to injected androgen in terms of the stimulation of aggressive behavior (Allee, Collias, and Lutherman, 1939). Some of the birds used were barely older than this and included flock-mates of the treated birds. When encounters involving birds less than one year of age with older birds were omitted, the multiple correlation coefficient fell slightly from 0.75 to 0.70. The path coefficients were almost identical except that that for the comb size fell to 0.31 from 0.35. Possibly difference in general size weakened the accuracy of the comb as an indicator since the older hens tended to be somewhat heavier and larger. On the other hand, senility may play a role. Degenerative changes occur in the pituitary of old fowl (Payne, 1941). There is some recent evidence which suggests the possibility that senile animals may become less sensitive to injected androgens (Hoskins, Levine and Bevin, 1939). One flock of our hens was approaching senility, but were still laying, during the last set of encounters in which they were used. However, no effect of age differences on success is evident from the gross data; of the 200 encounters, 36.5 per cent. were won by older birds, 39.5 per cent. by younger birds, and in 25 per cent. of the cases the opponents were of about the same age.

The behavior of the other bird is undoubtedly important. A hesitant individual will often take heart and attack when it observes that its opponent seems frightened. In only 33.5 per cent. of the encounters did an actual battle ensue, and 78 per cent. of the encounters were won by the bird that started the encounter. The longer the latent period before contact began the shorter a fight was likely to be and the greater the probability that one bird would submit passively.

Experience in winning or losing can be an important factor at times, and by purposeful application of this factor the results of a later encounter between a given pair of birds can often be reversed in a later encounter. It is a little difficult to extract suitable test cases in encounters of hens. Seven cases were tested in which the original loser had won from two to five encounters while the original winner had lost from three to six encounters just before the second meeting, and the results were reversed in every case. Ginsburg and Allee (1942) have recently brought out the marked importance of this factor of conditioning in mice by a series of carefully controlled experiments. Whether conditioning played much of a role in the present series of encounters is somewhat debatable, but a conscious effort was made to control this factor by not fighting any bird more than once a day. The more immediate history of a bird might perhaps be expected to exert the greatest influence; however, it is interesting to note in this connection that the correlation between winning a given encounter and success in the preceding encounter was exactly the same as the correlation with the second preceding encounter, that is, 0.66. This tetrachoric correlation was conveniently secured by use of computing diagrams prepared by Thurstone and Chesire.

Endurance is probably a factor when an actual fight takes place. By fighting the same tough hen over and over again in succession Schjelderup-Ebbe (1922) was able to make her yield and be subordinate to weaker

birds. During a battle it is obvious from the increasing slowness of movements of the birds that they are becoming more and more tired. Since none of the hens were fought more than once a day in the present series of encounters some measure of control over this factor was afforded.

The nature and importance of more completely unknown factors can merely be speculated on at present—differences in fighting skill, chance blows, differences in sensitivity to hormones, wildness, mild indisposition akin to illness, resemblance of the opponent to a despot or subordinate in the home flock, the details of past history, minor external disturbances, slight differences in handling, and errors in measurement perhaps have an aggregate effect of significant dimensions.

APPLICATIONS OF THE METHOD AND RESULTS

The significance and general implications of the problem will be developed elsewhere (Collias, 1943). The general importance of the statistical method employed is that it provides something of a model whereby the relative importance of the various factors which decide social dominance relations in various situations of ecological significance may be quantitatively evaluated. The present statistical method of evaluating the factors which make for high social level would have to be modified for each particular case, but this would probably not entail insurmountable difficulties.

One of the biggest complications and not adequately dealt with in this report since its influence was experimentally eliminated, is the interrelationship of territory. Schjeldrup-Ebbe's data indicate the possibility that in chickens, which have not generally been regarded as territorial birds, this factor may often outweigh all the others. However, even in nature, birds may on rare occasions be displaced from their territories by stronger rivals. Perhaps territorial influence could be measured by the distance from the territorial center.

More specific parallels of the general results to natural situations, at least cases where one factor apparently dominates the situation, can be cited even in the present inadequate state of investigation of social hierarchies in the vertebrates. At first thought, the size and weight factor is perhaps most obvious, *e.g.*, a general order of precedence to food in rough order of size differences is very common, for example, in birds of different species at a feeding shelf (Nice, 1929), or in different species of ducks and geese on a park lagoon (Jenkins, in press). The factor of male hormone is probably the important one in many situations. Males usually dominate females, and Lorenz (1931) states that young jackdaws rise in the peck order as they become reproductively activated, and much the same thing has been found by Shoemaker for canaries (1939). Coveys of quail and winter flocks of many other birds break up with the onset of the breeding season and the parallel rise in gonad activity and individual aggressiveness. Fighting is very common in groups of young male mammals (Alverdes, 1935). Examples of the action of thyroxin are more obscure and lie on more unstable assumptions, because of the complexity of its effects. In general, birds when moulting tend to retire to dense cover and hence to avoid conflict with other members of their species. The same retiring habit is seen during incubation when gonad activity is likewise reduced. Schjelderup-Ebbe (1922, 1935) has described a decided increase in aggressiveness of broody hens and such accords with the popular idea, but some evidence has been gathered in this laboratory which, while inadequate in itself, suggests the need for caution in relating such things as the defense of her chicks by a broody hen to position in the social hierarchy of the flock. The effective stimuli for types of aggressive behavior with different physiological bases may be very different.

SUMMARY

Initial encounters lie at the basis of the social order in flocks of chickens, as is known to be the case with a num-

ber of other vertebrates. To gain some insight into the factors which decide the outcome of initial encounters 200 pair contacts were staged in a neutral pen using normal, moderately inbred white leghorn hens from different flocks. Controlled factors included sex, territorial familiarity, and social facilitation. Evaluation of the less easily controlled factors was made mainly by the use of a modified biserial correlation formula. The degrees to which success in encounters was controlled by the more important factors were determined by the method of path coefficients which in the present instance was the same as the method of multiple regression.

Factors of major importance were male hormone output as indicated by comb size and thyroxin secretion as indicated by the complex of changes which accompany moulting. Social rank in the home flock had much less influence, and weight was of only small importance.

The multiple correlation coefficient of success with the four factors analyzed was 0.75. Forty-four per cent. of all factors were unknown or unmeasured in this analysis.

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